Section 822
Issue No. 4
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ELECTRICAL PROTECTION OF CARRIER EQUIPMENT

CONTENTS

1. GENERAL

1.1 This section provides REA borrowers, consulting engineers, contractors, and other interested parties with information for use in the design and construction of REA borrowers' telephone systems. It replaces REA TE & CM 822, Issue 3, dated December 1967. The purpose of this section is to discuss minimum protection requirements for carrier equipment and to explain what is expected of equipment now being furnished. This revision updates the information previously covered. Local grounding of metallic outdoor carrier equipment housing is very strongly recommended by this revision to minimize personal shock hazards. The material formerly contained in the appendix to this section has been updated and incorporated in new TE & CM 823, "Use of Gas Tube Arresters."

1.2 Carrier equipment should be capable of meeting the protection requirements of REA Specification PE-60, "REA Specification for Trunk Carrier Multiplex Equipment" or equivalent requirements contained in other REA carrier specifications. Suitable protection apparatus should be furnished by supplier, and used in the manner specified by the supplier.

All carrier equipment now on REA's "List of Materials Acceptable for Use on Telephone Systems of REA Borrowers" was accepted on the basis of test data or experience which demonstrated the acceptability of the equipment from the standpoint of protection considerations.

1.3 It is the supplier's responsibility to insure that the internal protection design is adequate; provide all the protection equipment except ground electrodes, wires, connectors, etc.; and provide protection practices for the equipment being installed. It should be noted that some protection apparatus, such as gas tubes and zener diodes, may be sealed within the equipment so as not to be accessible. This is done at the option of the supplier and depends on his views concerning field maintenance of these devices.

1.4 Most carrier equipment is provided with protector mountings that are accessible so the protectors can be serviced. The mountings are sometimes equipped to accommodate either gas tube or air gap carbon protection interchangeably. REA recommends the exclusive use of gas tubes to protect carrier equipment.

1.5 The protection apparatus used must coordinate with the inherent dielectric strength and surge current-carrying ability of the carrier equipment involved in order to be effective. Assuring this coordination is the responsibility of the equipment supplier.

2. PROTECTION STANDARDS

2.1 The electrical protection portion of Specification PE-60 contains the protection standards applicable to all carrier equipment including lightning protection criteria for cable carrier, open wire carrier, and carrier equipment using ac power. The protection standard does not require equipment to withstand the currents and/or voltages derived from direct contact with power lines as this is impractical. However, paragraphs 4 and 8 herein provide information on how to minimize equipment damage from ac power faults.

2.2 Specification PE-60 requires surge tests which simulate lightning conditions on cable plant and open wire plant. However, additional protection may be desirable where cable type subscriber carriers are used on extensive runs of open wire. (See Outside Plant Carrier Protection, paragraph 9).

3. ELECTRONIC EQUIPMENT PROTECTION DESIGN

3.1 Protection design is based on preventing lightning surges in excess of the surge capability of any component of the equipment from reaching that component. The weakest components are usually semiconductor

devices. Many semiconductors can tolerate only very small surges, and need to be protected by low voltage devices.

Because the low voltage protection devices themselves have limited surge capability, they, in turn, need to be protected by higher voltage protection devices whose characteristics are tailored to coordinate with the surge limitations of the low voltage protection. Equipment may contain several stages of protection, such as high, intermediate, and low voltage protection apparatus for these reasons.

3.11 The technique for determining if the protection design objectives have been met is to subject the carrier equipment to surge tests with the high voltage protection apparatus removed (see PE-60). The magnitude of the applied surge is equal to the theoretical maximum which the carrier equipment can receive when field mounted with the high voltage protection in place. When intermediate voltage protection apparatus is also used, additional tests are made at low voltages with this intermediate protection removed.

3.2 Carrier is often used on long toll circuits and frequently provides many channels on one or two physical pairs. Continuity of service on carrier circuits is very important. Gas tubes are recommended instead of carbon blocks for protection to avoid service outages which could otherwise occur from grounded carbon blocks. Some gas tubes can be mounted directly on printed circuit boards. Varistors, zener diodes, current-limiting resistors, high-loss transformers, inductors, resistor-capacitors, shielding, and isolation techniques are other common methods used to protect transistorized circuitry.

3.3 The degree of protection needed depends on the circuitry and the environment of the installation. When transistors are buffered by passive circuitry, such as filters, transformers and relay windings less protection is necessary. Many CO terminals are adequately protected by main distribution frame (MDF) protectors for these reasons. Solid-state components being more sensitive to lightning damage may need additional protection. An example of equipment which can be severely exposed to lightning is the four-wire repeater shown in Figure 1. Terminals A, B, C, D, E, F, G, and H are connected to cable pairs. Repeaters such as these are installed at regular intervals along cable routes.

3.4 Gas tube arresters should normally be used as high voltage protection to protect against the more severe electrical disturbances. They operate as voltage controlled switches that are ordinarily open. When surge potentials exceed their operate value, the "switch" closes, providing a means of routing the surge around components which could be damaged.

3.41 Gas tube arresters may be used either in series from input to output (see Figure 3A) or in parallel (as with buffer protection). When used in parallel, breakdown of the first arrester will usually prevent breakdown of the second. When arresters are used in series, the breakdown of the combination will be higher than that of a single arrester, with the possible exception of some 3 electrode units. Generally, when two arresters of the same voltage rating are used in series, the breakdown will be 1.4 to 2 times the breakdown of a single unit.

3.42 Gap type arresters, either carbon electrode air gap or gas tube, require a finite but very short time to operate. In addition, the breakdown range of these units is usually quite wide. One typical type is listed as breaking down from 250 to 600 volts. As a result, additional low voltage protection having extremely fast operation and a precise operation level, is frequently required for protection of delicate electronic components.

3.5 Air gap or gas tube arresters effectively protect equipment during that time when all of the arresters subjected to the surge are conducting simultaneously. However, most surges are not severe enough to operate the high voltage protection. This means that the equipment itself or the equipment with low voltage protection must be capable of withstanding voltage surges up to the maximum breakdown value of the high voltage protectors.

3.6 Figure 1 is an example of a typical scheme of overvoltage protection provided for a four-wire carrier repeater. With the exception of gas tubes 20 through 27, the components are usually mounted on a printed circuit board.

3.61 Metallic (tip to ring) Surge Protection. In Figure 1, zener diodes 9 through 16 protect the amplifier circuitry from small metallic surges that could damage delicate electronic components. Resistors 1 through 8 limit currents that can flow in the zeners and equipment to a safe value. As this current increases, the voltage drop across the resistors becomes greater until it is sufficient to cause gas tubes 20 through 27 to fire and bypass the surge completely around the repeater electronics. Care must be taken to assure that the gas tubes fire before the zeners or other electronics circuitry are damaged.

3.62 Longitudinal (input to output) Surge Protection. One of the most vulnerable points in a repeater is the power supply voltage dropping diode, zener 17 in Figure 1. On a longitudinal surge, the voltage drop across the power supply diode 17 and resistor 18, increases to the firing level of gas tube 19. At this point the tube fires and bypasses the surge around the power supply.

3.7 Protection capable of passing Specification PE-60 tests can be accomplished by many different protection designs. The example shown was chosen because of its broad use of available techniques. Component ruggedness, circuit design, and protector characteristics used in each make and type of equipment determine the most economical protection design solution.

4. POWER SUPPLY EQUIPMENT PROTECTION

4.1 Most carrier systems require that power be furnished over the carrier physical conductors from central offices. Other carrier systems require a commercial ac power source. Commercial power lines are exposed to lightning and switching surges, and protection may be needed to prevent damage to the carrier equipment connected to this source.

4.2 The preferred carrier supply protection for ac powered equipment unless built-in protection is included in the design, is shown by Figure 2. The secondary arrester, steel conduit, gas tube, and self-restoring circuit breaker act together as an electrical protection circuit. It is important that the secondary arrester be installed at the weather head, and that a <u>steel</u> conduit be run from the weather head to meter base. The steel conduit provides reactance to lightning surges. This increases the likelihood of operation of the secondary arrester, providing it is installed <u>at the weather head</u>. The power protector consists of a heavy-duty gas tube and self-restoring circuit breakers. When the gas tube breaks down and conducts, the large current which can be drawn from the power system tends to force the tube to hold over. At this point the circuit breaker opens and permits the tube to restore. After the tube has restored to the non-conducting condition the circuit breaker recloses and power is returned to the carrier unit. If nonself-restoring breakers, or fuses, were used a man would be required to visit the site after each operation of the arrester to reset the breaker.

4.3 Figure 2 protection is usually justified only when the carrier equipment is pole mounted. It is not usually necessary for ac powered single channel station carrior subscriber terminals. Protection of most single channel station carrier from ac surges is accomplished by using a built-in high loss isolation transformer. This "shields" the dc side of the equipment power supply and makes it unnecessary to provide Figure 2 protection.

5. PERSONAL SHOCK CONSIDERATIONS

5.1 Many studies have been made by others on the dangers of electric shock. Based on the reported test results of such studies, REA recommends that special precautions be taken whenever contact with an energized circuit can provide a shock severe enough to cause ventricular fibrillation. Ventricular fibrillation is likely to occur when a 60 Hz

rms ac current of 0.030 to 2 amperes passes through one's chest cavity. Some studies have shown that ac is more dangerous than dc by a ratio of approximately 3 or 4 to 1 and that duration of the current is a major factor.

5.11 The above-mentioned studies show that the resistance of a dry adult human body is approximately 100,000 ohms. Wet or damaged skin reduces this figure greatly. Fifteen hundred ohms is a conservative figure for an adult male with intact skin with prespiration dampened hands. This value has been generally selected as the assumed body resistance for safety calculations.

5.12 Because of the above, it is REA's view that every circuit from which in excess of 35 mA rms ac or 120 mA dc can be drawn through a 1500 ohm resistor (50V rms ac or 180V dc) connected from line-to-ground, or 37 mA rms ac or 133 mA dc through a 1500 ohm resistor connected from line-to-line, should be classified as hazardous. The slightly greater values are permitted from line-to-line because of the greatly reduced probability that line-to-line contacts would provide a low resistance path through the chest cavity. All possible steps should be taken to eliminate hazardous circuits from the system. Exceptions to the above recommendations are circuits whose outside plant portions are entirely in cable, or cable and jacketed distribution wire which prevents more than finger contact, and from which not more than 50 mA rms ac, or 180 mA dc, can be drawn from line-to-ground for 5 seconds through a 1500 ohm resistor. These circuits may be classified as "limited access circuits." Limited access circuits are tolerable for use within a telephone system, however, special precautions should be taken when working on circuits of this classification. The precautions should include, as a minimum: (1) use of tools with insulated handles, (2) rubber mats on the floor beneath the MDF appearance of these circuits, (3) distinctive color coding each appearance of these circuits in the CO, and (4) insulating shields over exposed terminals of these circuits to prevent inadvertent contact with them.

5.13 In an effort to decrease hazards, and lessen special and costly precautions required when working on high voltage circuits, many of the present carrier systems use either current limiting, or a quick disconnect arrangement to keep plant personnel from being subjected to hazardous current for more than a fraction of a second.

5.2 Interconnection of power and telephone grounds is very strongly recommended whenever ac power is used at a location, in order to protect personnel. The effectiveness of the protection is also improved by a low resistance ground. A 5-ohm or lower resistance <u>telephone ground</u> is recommended (in addition to interconnection with the power ground) if it can be achieved at a reasonable cost.

6. GAS TUBE PROTECTION APPLICATIONS

6.1 Maintenance expense and continuity of service are the controlling factors when considering gas tube protection. While gas tubes are more expensive than carbon blocks on a first-cost basis they substantially reduce maintenance and equipment outage time <u>when properly</u> selected. As stated earlier gas tube arresters are recommended for application on <u>all</u> carrier circuits which require arresters. Specifying the make and type of gas tube used is the responsibility of the manufacturer. When replacing carbon block protection, or adding buffer protection to existing equipment the REA borrower should consult equipment manufacturers as to the proper arrester breakdown voltage range for use with its equipment.

7. CENTRAL OFFICE EQUIPMENT PROTECTION

7.1 Carrier equipment mounted in a central office should be grounded by means of a #14 AWG or larger copper conductor connected to the central office ground bus. This gauge wire should be used for branch connections only, long runs such as from bay to CO ground bus to which many units are connected should be made with #6 AWG wire. Interconnection of the power service and central office grounds should be made with a #6 AWG copper wire, or equivalent, or larger, as recommended in TE & CM 810. Specific instructions should be furnished by the manufacturer when additional protection apparatus is needed other than the MDF protectors. NOTE: REA's electrical protection tests presume that 3-4 mil (white coded) carbons, or equivalent gas tubes will be used as MDF protectors for electronic equipment. <u>Use of higher voltage arresters may lead to equipment damage</u>.

7.2 When remote repeaters and/or terminals are powered by high voltage (see paragraph 5.1) on the carrier pairs from the central office, it is strongly recommended that automatic disconnect equipment be furnished and installed at the office. This equipment automatically disconnects power from the carrier pair whenever a low impedance ground is suddenly introduced on the pair. The feature should effectively protect personnel from shock hazards due to sustained contact with power.

7.3 In order to reduce the risks from hazardous circuits in the central office, the use of "dead front" or semi-dead front" frames is highly recommended. Terminal blocks and protection modules at which these circuits appear should be color coded with a bright color to alert the maintenance man to the hazard. In addition, rubber mats should be used where personnel normally stand to work on hazardous connections.

8. JOINT USE CONSIDERATIONS

8.1 Where multigrounded neutral (MGN) power lines are built on joint poles with either open wire, cable, or other aerial telephone facilities, special problems can occur with carrier equipment protection. Figure 4 illustrates this situation. The effectiveness of the MGN as a carrier equipment ground depends on how often it is grounded, as well as how low a resistance each ground is. Poor MGN grounding does not usually affect line wire or cable pair protection, but can adversely affect carrier equipment protection. In general, carrier is presently designed to withstand lightning but not power faults. Self-clearing power faults are typically of 67 to 350 milliseconds duration or even longer, whereas a lightning stroke is typically of 50 to 150 microseconds duration. Power fault current reaching carrier equipment is usually damaging because of its relatively <u>long time duration</u>. Carrier equipment must be protected from power fault current either by a well grounded MGN or by special techniques.

8.2 Power faults to ground can energize portions of an MGN if it is not effectively grounded (usually because of high earth resistivity). For example, an MGN conductor with a 5-ohm ground, when subjected to a 1000 ampere fault current, would have a potential of 5000 volts with respect to remote earth ground. In fact, no "grounding" conductor is at true ground potential except when no current is flowing in the conductor. If carrier physical circuits are grounded to an MGN as shown in Figures 4B and 4D, when the IZ drop across the ground resistance exceeds the breakdown value of the telephone arresters, they will break down in the reverse direction as shown in Figure 4D. This provides a short circuit between the energized portions of the MGN and telephone pairs for the duration of the fault. Fault current can flow from the energized portion of the MGN through telephone pairs to remote ground under these circumstances. Extensive carrier equipment damage can occur from this; however, from a personel shock hazard standpoint, there are situations where this damage may have to be accepted. In Figure 4D had the carrier not been bonded to the pole ground, the 5000V appearing from the MGN to remote ground would appear from the pole ground to the repeater cabinet. As these units are in close proximity, and can be contacted by the general public, the result could be a severe shock hazard.

8.21 Carrier equipment trouble caused by power system faults can be avoided by isolating carrier protectors from the MGN. Figures 3 A-C show examples of repeaters powered from a remote dc source, which have been isolated from the MGN. Where the carrier unit is on a nonjoint use pole, or is mounted on a joint use pole which does not have an MGN vertical pole ground wire, isolation from the MGN and protection can be arranged as shown on Figures 3B, 4A, and 4C. Carrier protection and MGN isolation should be accomplished without disconnecting the MGN from the main cable shield or strand. Bonds between

the MGN and the main cable shield or strand should not be removed because this will create a hazard to the public, to telephone personnel, and to plant in the event of a power contact.

8.3 The Figure 3A repeater has built-in high dielectric strength between the equipment chassis and the equipment housing. Repeater housing designs of this type are very convenient for isolating carrier protection from the MGN. The arresters in the protection arrangement shown by Figure 3A operate in series as they are not grounded. Figure 3A is an example of nongrounded by-pass protection. All cable trunk carrier equipment manufactured after April 1972, is required to be capable of employing this mode of protection. NOTE: If the equipment housing is metallic, it should be connected to a local ground or power MGN if one is near by. This connection reduces personnel shock hazard for passerby who may come in contact with the cabinet and a good local ground. With the cabinet grounded, adequate dielectric strength between cabinet and chassis is essential for proper operation of the nongrounded bypass protection. NOTE: For personnel safety, the equipment chassis should be connected to the equipment housing temporarily while performing maintenance or testing at the repeater location. The housing release mechanism on some housings accomplish this automatically when the cover is removed; others require that the maintenance man clip a cable between the housing and chassis. When the manually attached cable method is used, caution should be exercised when removing metallic housings. Should the housing contact the floating chassis while a foreign potential is present, the maintenance man could receive a shock. Some manufacturers use plastic covers to eliminate this shock hazard.

8.31 Figure 3C is an example of an alternate approach to nongrounded bypass protection. In Figure 3A two arresters in series must break down for a surge to bypass the repeater from input to output. With Figure 3C only a single arrester must break down for a surge on either line to bypass the equipment. The 3C configuration has the disadvantage that it cannot be used for grounded protection as there is no common "ground point" as with 3A type protection. There is also a problem in obtaining protector mountings for this arrangement.

8.4 When a metallic buried plant housing is mounted on a power pole, the grounding connector of the housing should be bonded with a #10 AWG bare copper wire to the vertical pole ground wire, if present, on the pole. The purpose of this bond is to maintain the ground wire and the buried plant housing at the same potential thereby preventing a shock hazard that otherwise might exist during a fault condition on the power line.

8.5 With certain types of cable carriers, the carrier equipment manufacturers have recommended that the carrier equipment not be connected to an electric system ground. In such instances carrier

equipment housings and/or metallic buried plant housings enclosing carrier equipment should be bonded to vertical pole ground wires as required herein in paragraph 8.4 but the carrier circuitry and chassis should be isolated from the metallic housing by insulation having at least 20 kV dc dielectric strength. The provision of this dielectric between the carrier circuitry and the housing makes it possible to use floating by-pass protection for the equipment and protection to the public by locally grounding the housing. It is the responsibility of the carrier equipment suppliers to provide the 20 kV dielectric strength between the carrier circuitry and chassis and the metallic housing if bypass protection is required.

8.51 If a supplier specifies that the arrester in a carrier be grounded but not to an MGN, it is important that the separate ground electrodes be physically separated at least 10 feet to achieve effective isolation.

9. OUTSIDE PLANT CARRIER PROTECTION

9.1 Low maintenance and protection from ac power faults are major protection considerations. Lower maintenance can be achieved by using gas tube protection as discussed in paragraph 6. Damage from ac power faults other than direct contacts, can be avoided by isolating carrier equipment protection from the MGN, as discussed in paragraph 8.

9.2 Where cable carrier is exposed to lightning surges from open wire, two additional protection methods should be considered. Figure 5 shows an example of an installation where additional protection in the form of a heavy duty gas tube is provided at an open wire tap. It is assumed that the carrier equipment is installed on the cable facilities. Figure 6 shows an example of an installation where additional protection in the form of heavy duty gas tubes are used on each side of the carrier equipment. The gas tube ground electrodes shown in Figures 5 and 6 protection should be tied to low impedance earth grounds. Figures 5 and 6 protection is desirable for cable type carrier equipment installed on open wire where the protective devices furnished with the equipment are standard or light duty gas tubes.

9.3 When Figures 5 and 6 protection is being considered, equipment selected should have performance characteristics which meet the carrier equipment manufacturers' recommendations. Improper selection or use of additional protective devices may not be effective. Generally, installation of carrier equipment on open wire or cable facilities requires no additional protection measures other than those specified by the manufacturer.

9.4 Some repeater equipment does not contain any dielectric material between the equipment chassis and equipment housing. Furthermore, the shield of the stub cable of the repeater may be bonded to the equipment housing and to an aerial cable shield. The aerial cable shield is bonded to the cable strand and the cable strand is usually bonded to the MGN, as shown by Figure 3A-C. Under these conditions if the criteria of paragraph 8.4 do <u>not</u> apply, the carrier protection can be isolated from the MGN by removing a 4-inch section of the stub cable shield and then repairing it with vinyl tape. This shield opening is called an insulating joint (see Figure 3B). In order to reduce personal shock hazard, the equipment cabinet should still be grounded to a local earth ground. The use of the insulating joint prevents surges which may have gotten on the cable shield at a remote location from getting onto the cable pairs at the repeater. This form of grounded protection does <u>not</u> prevent surges which cause the local ground to rise in potential from getting onto the pair; however, it should be of use in areas where a good local ground may be easily achieved, and where power contacts to cable shield are a common problem.

10. CARRIER PROTECTION AT A SUBSCRIBER'S PREMISES

10.1 Station carrier may require that some equipment be installed in or on the subscriber's premises. The common grounding practices in accordance with TE & CM 805, "Subscriber Station Protection", should be followed in those cases. It should be noted that the primary protection objectives, when installing any devices on a subscriber's premises are to protect the subscriber against electric shock and his premises against fire. As a result, connection of the telephone system ground to the electrical system ground, and to a metallic water system, if such is available, is very strongly recommended from a safety standpoint.

10.2 All commercially powered telephone equipment installed in or on the subscriber's premises should be listed by Underwriters' Laboratories, Inc., (UL). This UL listing provides a reasonable assurance that equipment installed on the subscriber's premises will not cause injury to either personnel or property when the equipment is handled in a reasonable manner.

10.3 Other specific instructions should be provided by the manufacturer.

11. CHARACTERISTICS OF PROTECTION EQUIPMENT

11.1 <u>Lightning Arresters</u> - The degree of protection that lightning arresters provide depends on their speed of operation, their breakdown value, their IZ drop after breakdown, and amount of the total current they can conduct, thereby quickly reducing the disturbing potential to a safe value. A knowledge of (1) the characteristics of

the carrier equipment components subject to damage from electrical disturbances, (2) the characteristics of the arrester, and (3) the general characteristics of the electrical disturbances is necessary for a satisfactory installation. As a result, the borrower should rely heavily on the equipment manufacturer for guidance in this area.

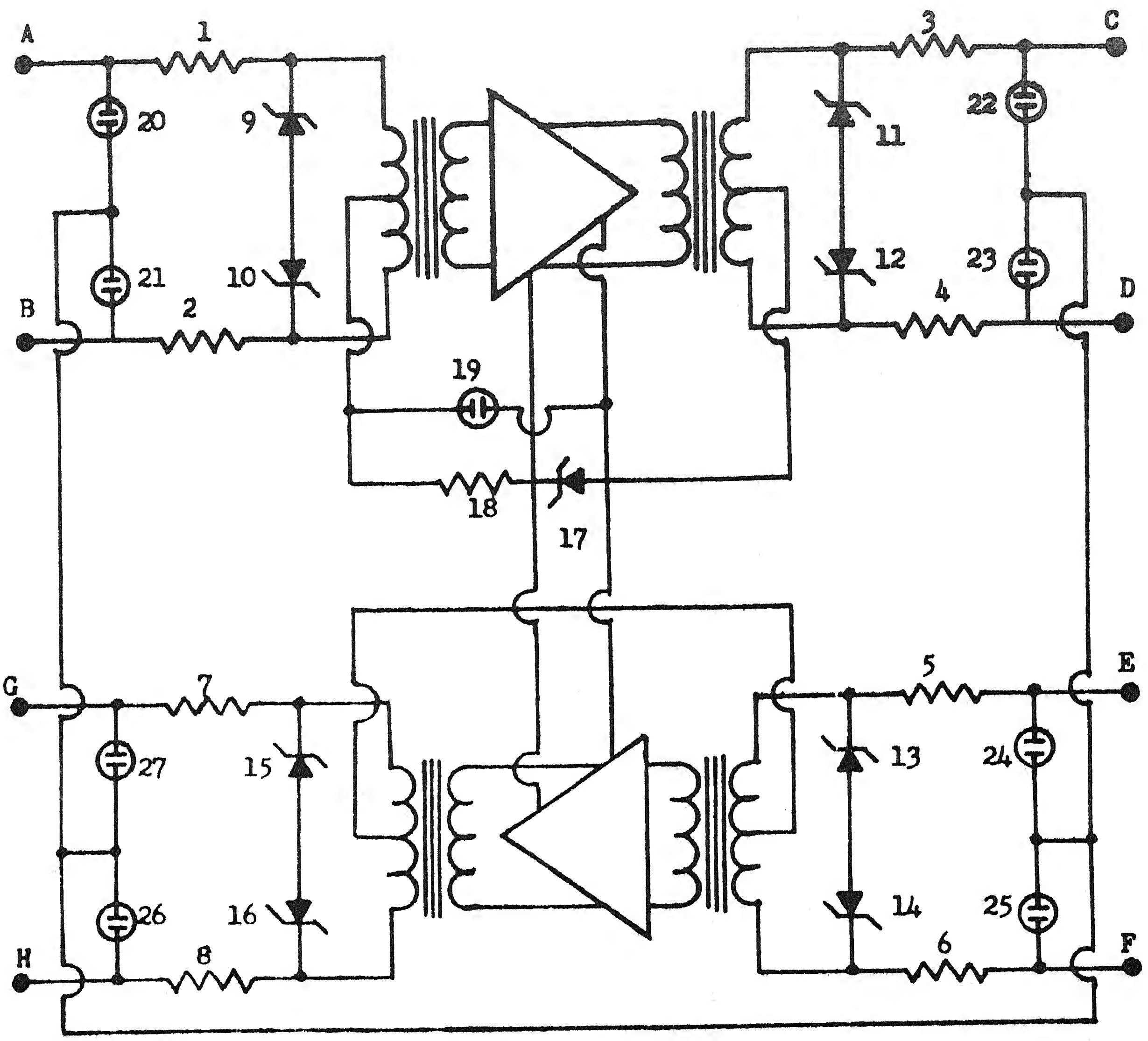
11.2 Gas Tubes - Gas tube arresters can be obtained in both two-element and three-element configurations. Gas tubes can be purchased that operate at many different dc breakdown values, beginning as low as 90 volts. In order to be effective the dc and surge breakdown voltages of the tubes must coordinate with the dielectric strength and surge current carrying ability of the equipment they are intended to protect. There are several important performance variations among the gas tubes currently available. Some of the more important characteristics include: striking voltage on 500 Volt/microsecond (cable) or 10,000 Volt/microsecond (open wire) wave fronts, short-duration surge current capability, 60 Hz power current capability for 11 cycles duration, device life when subjected to repetitive 500-ampere surges, dc holdover ratings, or dc clearing potential, impedance when conducting, glow range, ruggedness of construction of seal, leakage resulting from high humidity or dc voltage, and consistency and predictability of operation. Gas tubes generally protect equipment as well as carbon arresters and require far less maintenance. For a comprehensive discussion of gas tube arresters, see REA TE & CM 823.

11.21 One area of particular concern in the use of gas tubes on carrier systems is line-to-line dc holdover. When power supply voltages of ± 135V or higher line-to-ground is employed, line-to-line voltages may exceed the dc holdover capability of some tubes. The three electrode gas tube may be particularly vulnerable to this problem.

11.3 Secondary Arresters - A secondary arrester whose surge breakdown voltage does not exceed 2000 volts peak should be furnished wherever ac power is supplied to carrier equipment. This arrester is a two- or three-pole device providing valve action from line to ground when power line voltages exceed about 175 volts rms. When applied to a single phase, two-wire lead to carrier equipment, the two line leads of the protector should be connected to the phase conductor in parallel and the ground lead should be connected to the grounded neutral-conductor. Since secondary arresters have been furnished in the past as protectors for watt-hour meters having dielectric strengths of 9 to 10 kV, some secondary arresters available on the market are not satisfactory as protectors for carrier equipment whose surge dielectric strength is usually less than 2 kV. It is essential that secondary arresters for carrier protection be selected only from the "List of Materials Acceptable for Use on Telephone Systems of REA Borrowers."

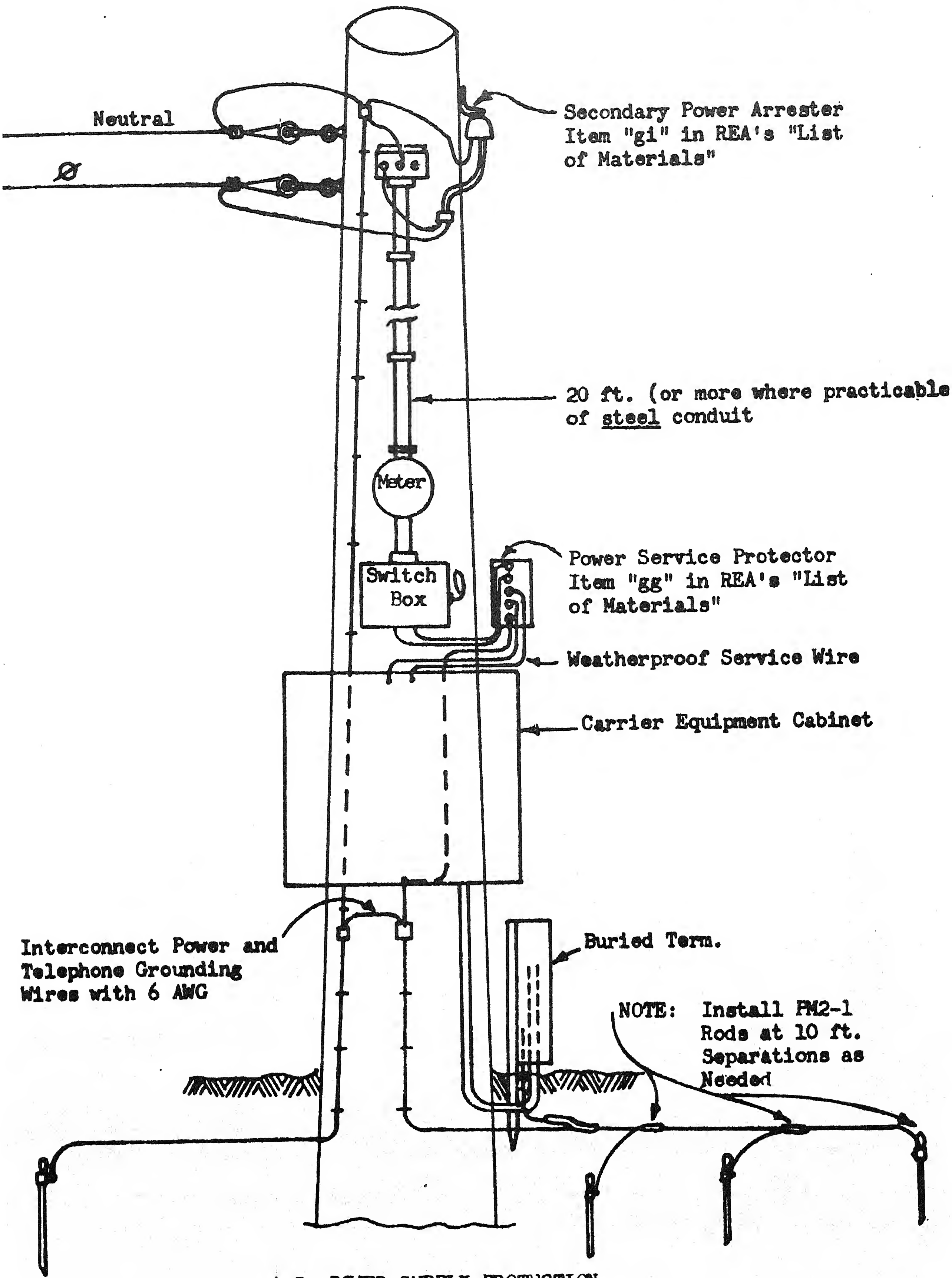
11.4 Drainage Units - These devices are used to reduce electrically induced 60-cycle voltages which are caused by capacitive coupling of power lines in joint use or parallel construction with open wire telephone circuits. In addition to causing noise and signaling problems, this induction may be sufficient to cause a hazardous shock to the lineman. Some of these units operate satisfactorily only at voice frequencies while others function well at both voice and carrier frequencies. Drainage units included on our List of Acceptable Materials are suitable at both voice and carrier frequencies. These units should be used as described in REA TE & CM 820, "Open Wire Circuit Protection."

11.5 This section is directed at protection of the average carrier installation. For situations of persistent outages, carrier in close proximity to power stations, etc., consult TE & CM 825, "Situations Requiring Special Protection."



1 thru 8 - current limiting resistors
9 thru 16 - Zener diodes - low voltage protection
17 - power supply diode
18 - current limiting resistor
19 - low voltage gas tube
20 thru 27 - gas tubes - high voltage protection

Figure 1 - Protection of 4 Wire Simplex Fed Repeater



A.C. POWER SUPPLY PROTECTION

Figure 2

REMOTELY POWERED REPEATER - ISOLATED FROM MGN

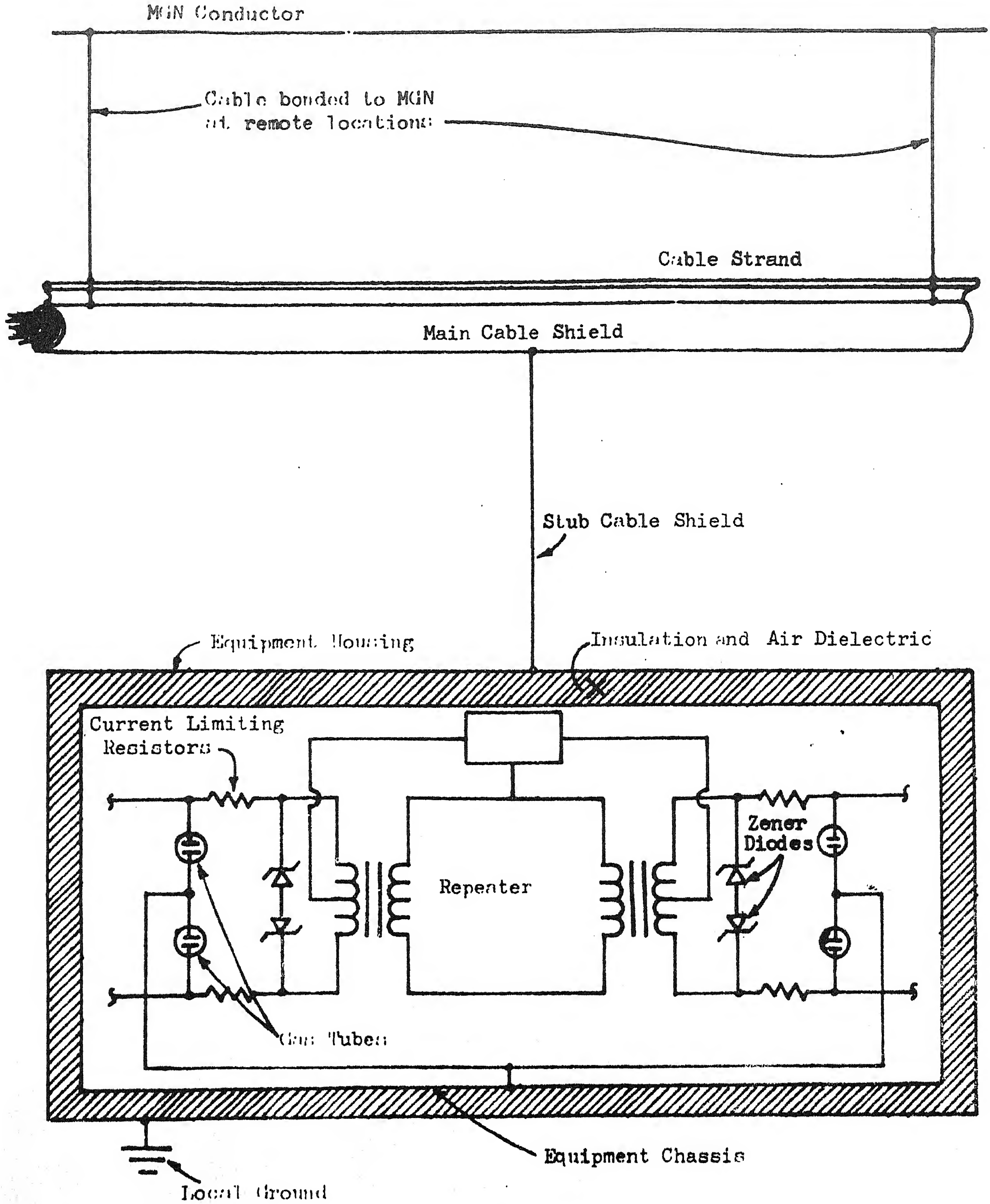


Figure 3A

REMOTELY POWERED REPEATER - ISOLATED FROM MGM

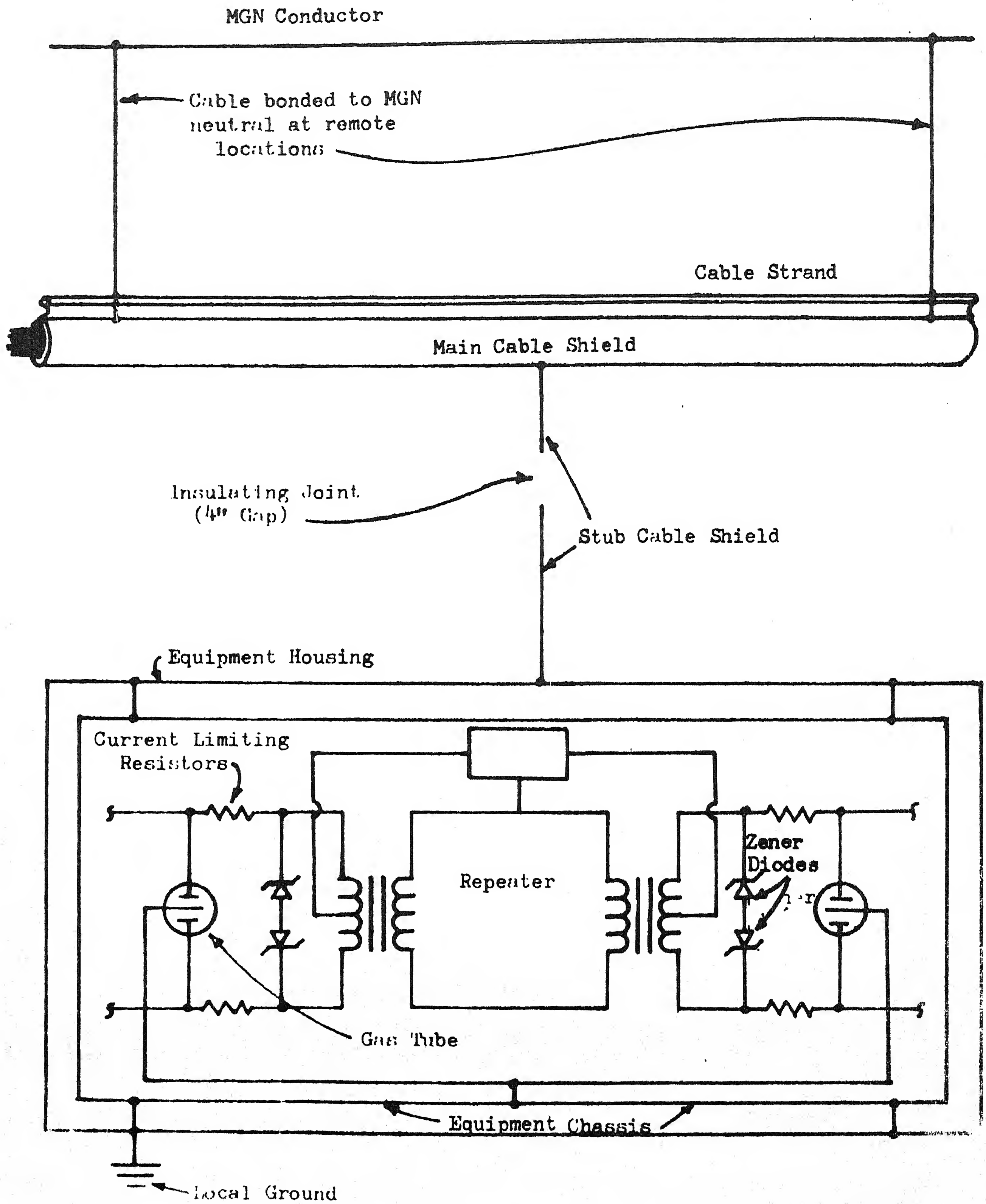


Figure 3B

REMOTELY POWERED REPEATER - ISOLATED FROM MGM

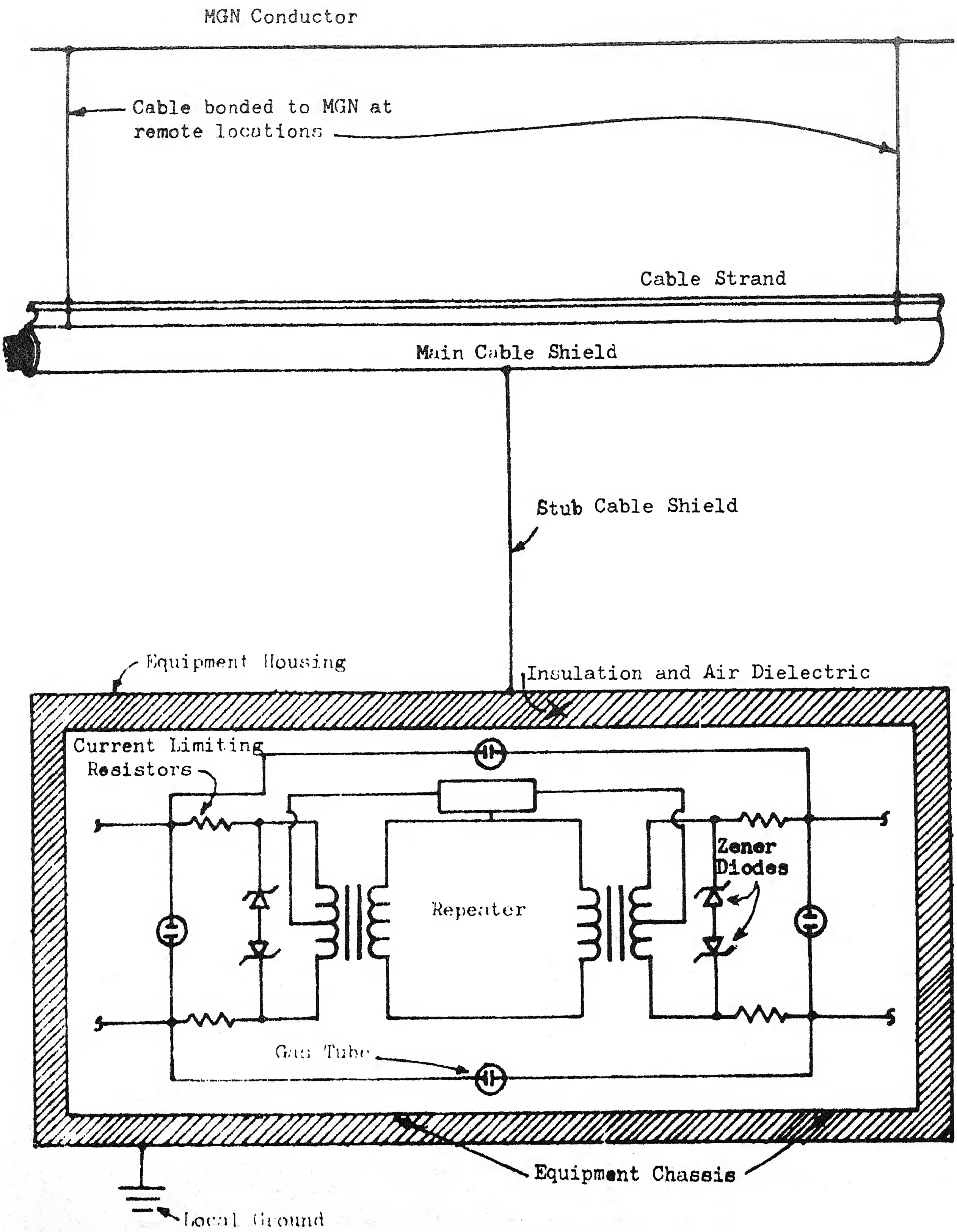


Figure 3C

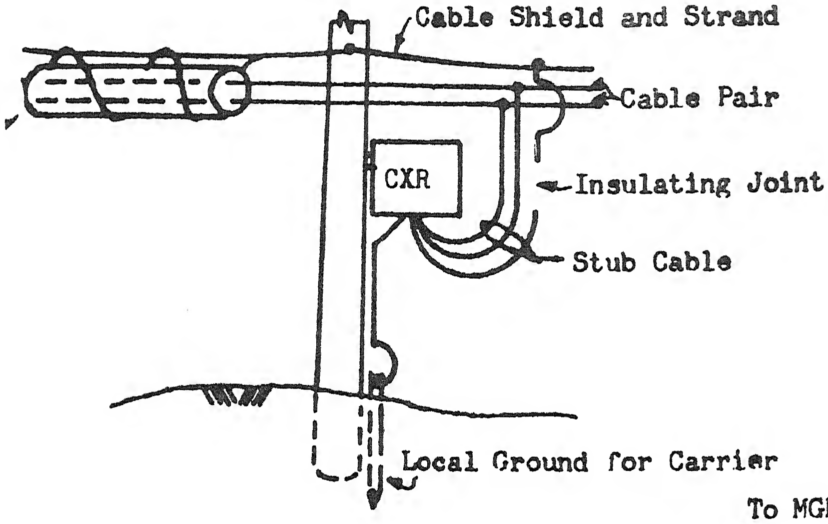


Figure 4A Local Grounding

NOTE: Figures 4A and 4B show grounding arrangements when lack of dielectric prohibits use of floating by pass.

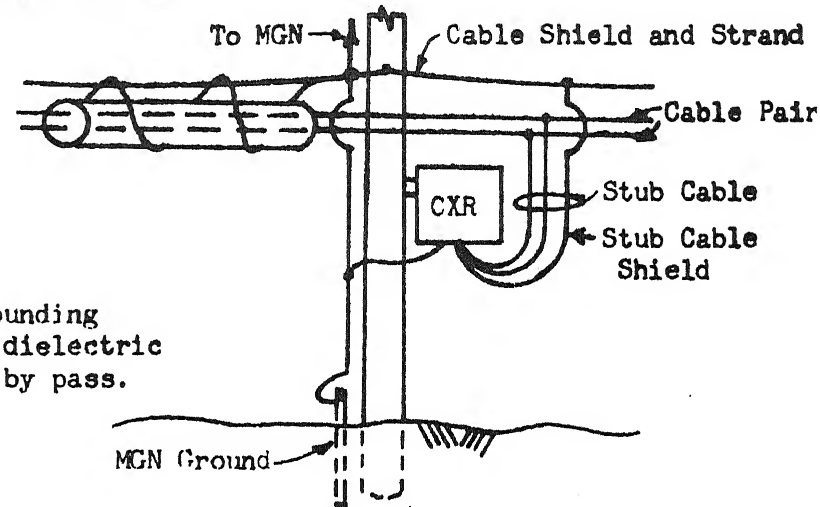


Figure 4B - Grounding to MGN

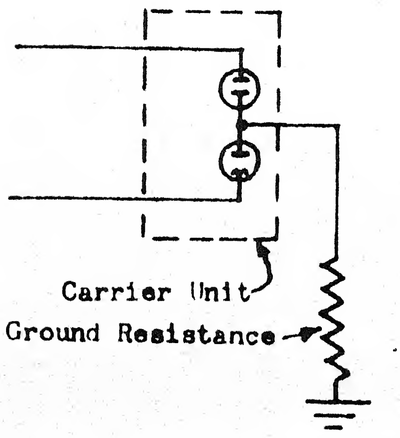


Figure 4C - Remote Unit-Isolated from MGN

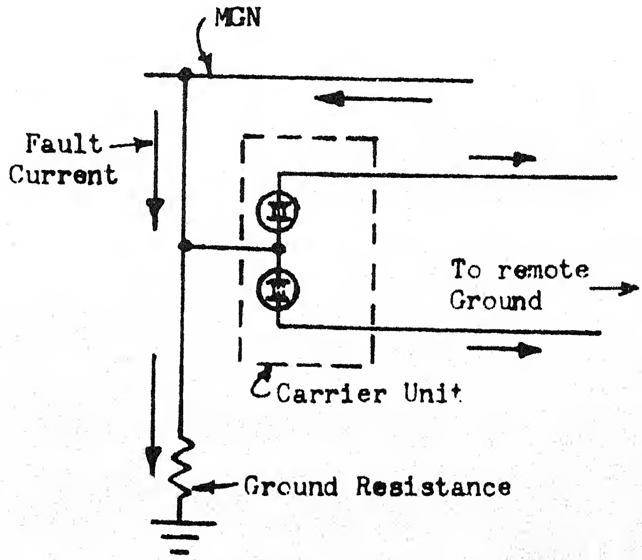


Figure 4D - Unit on Pole with MGN Ground Bonded to MGN

Figure 4 - Grounded Joint Use Carrier Protection

ADDITIONAL PROTECTION - OPEN WIRE TAPS

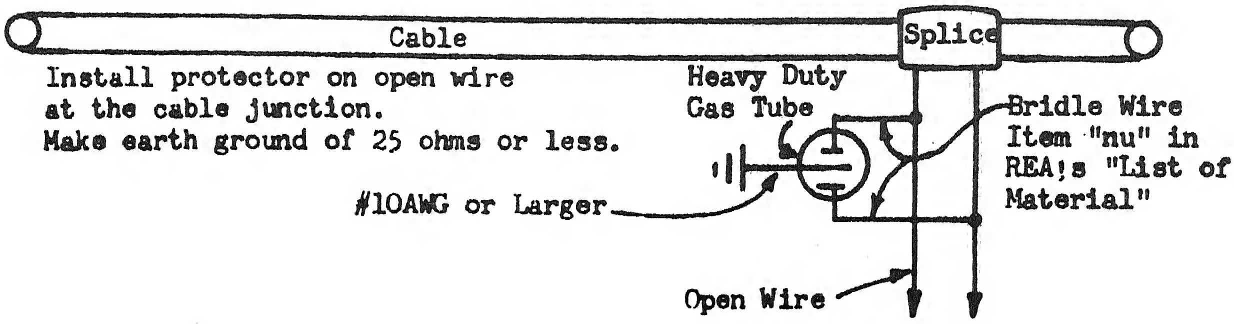


Figure 5

ADDITIONAL PROTECTION - OPEN WIRE

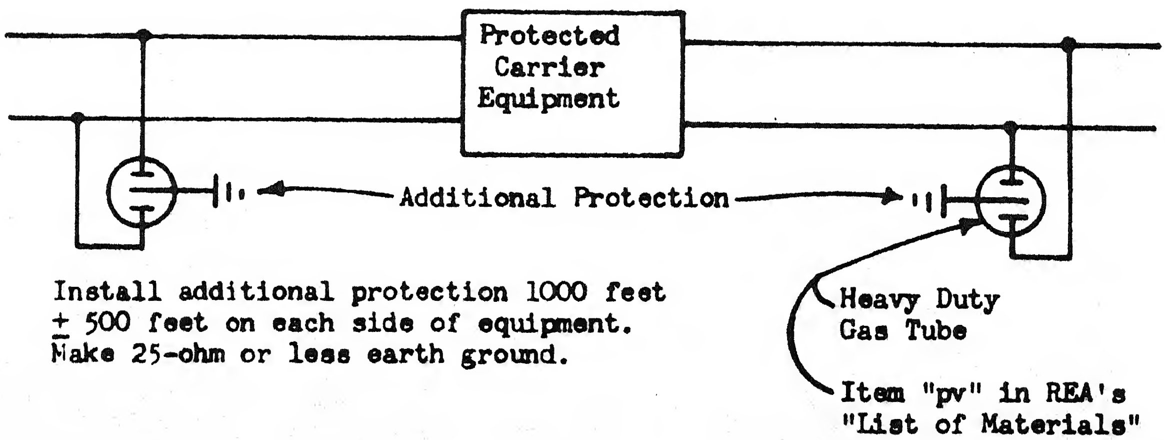


Figure 6